Funderingar kring broraset i Minneapolis

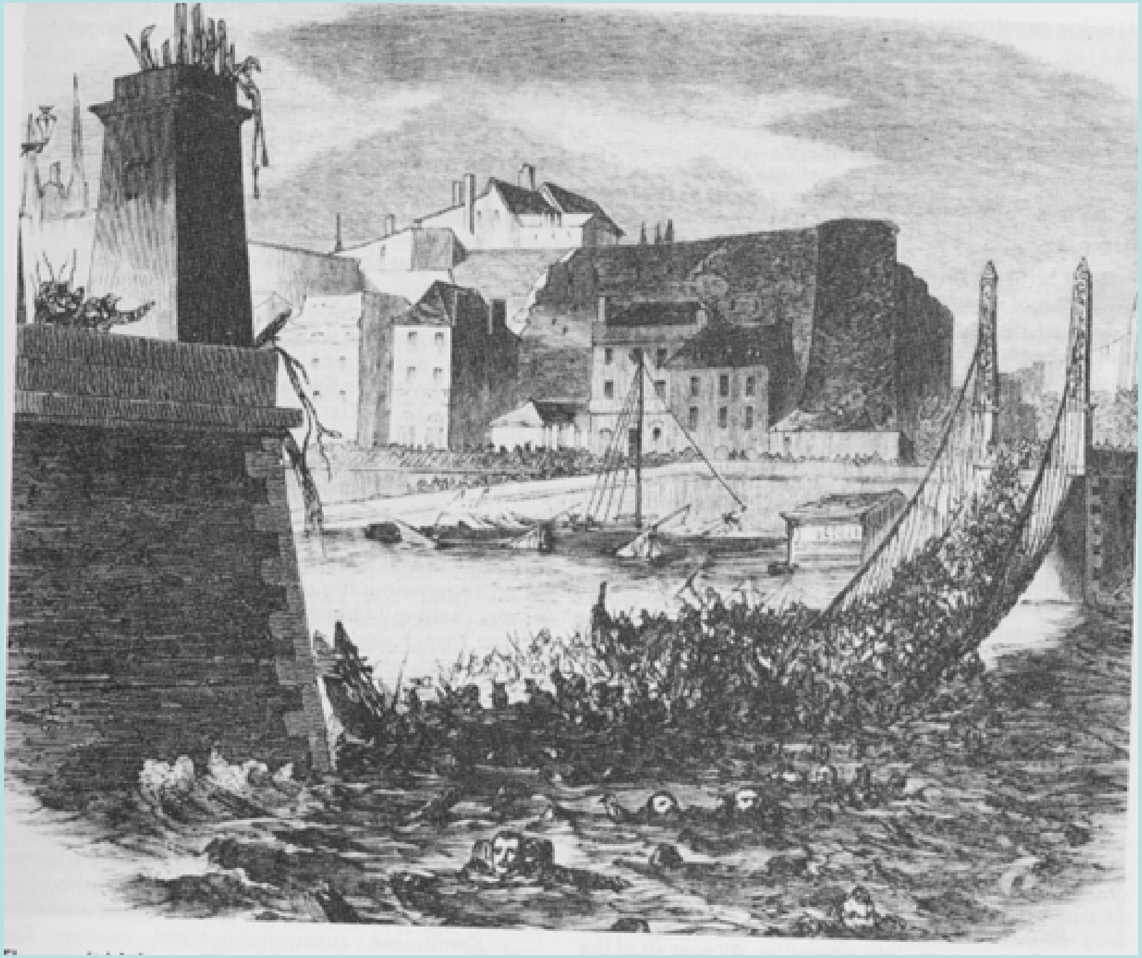
Peter Collin
Professor samverkanskonstruktioner, LTU
Ansvarig Teknikområde Bro, Ramböll Sverige

LULEÅ
TEKNISKA
UNIVERSITET

Några exempel på brokatastrofer

Basse Chaine
Frankrike 1850, 226 soldater drunknade.

Dåligt underhåll, för många soldater på bron.
Man gick i takt.

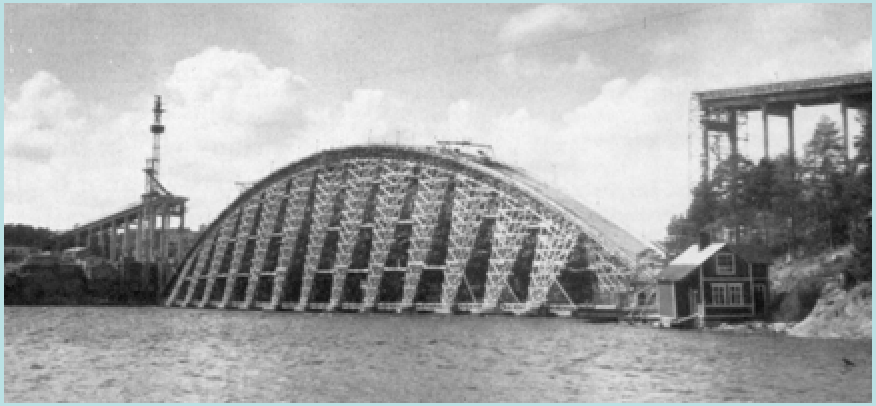


Tjörnbron, 1980. Underliggande bågar i form av
avstyvade stålrör.

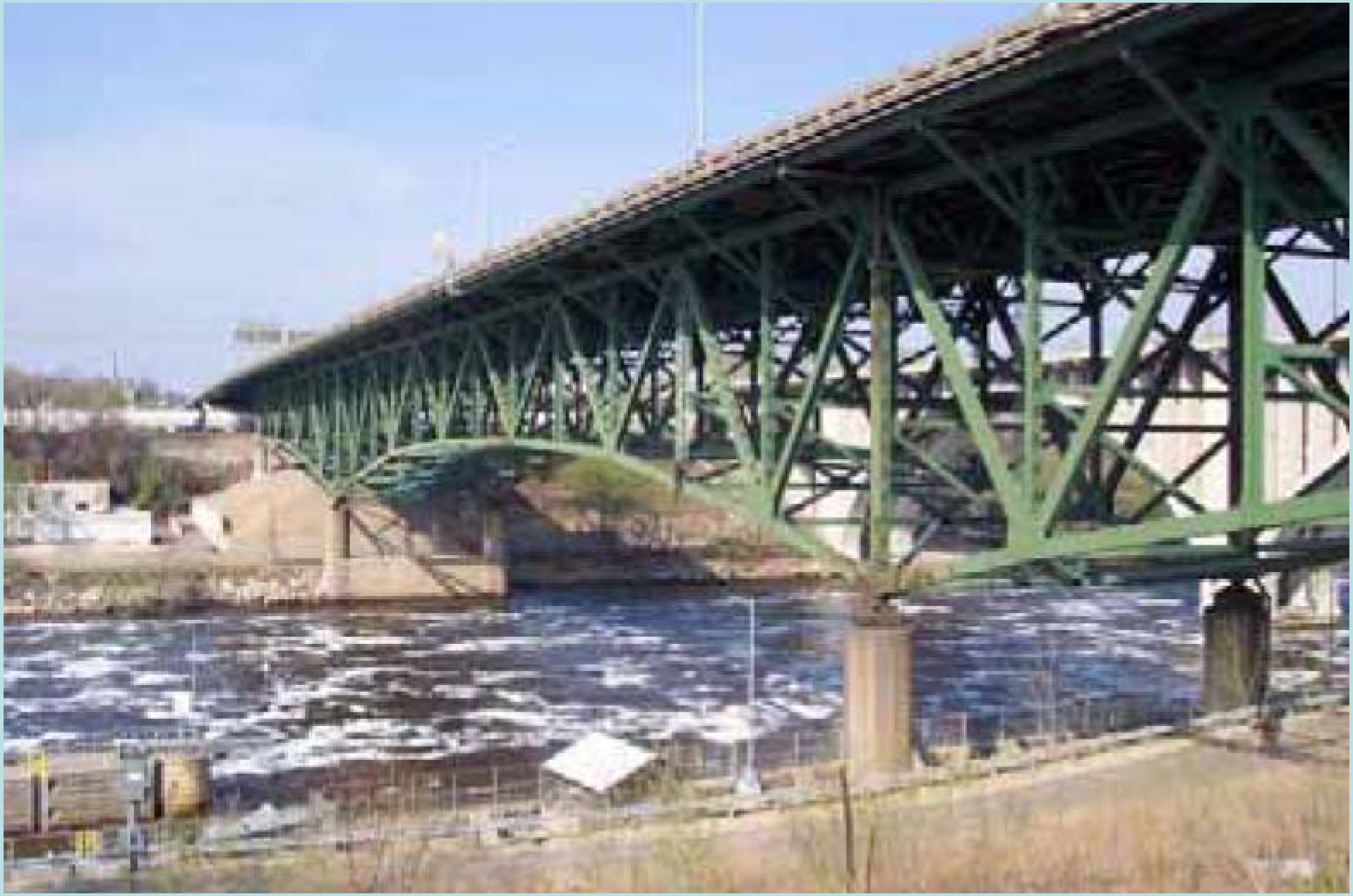
Tjörnbron, 1980. 8 människor dog efter påsegling av brons underliggande båge. Alternativ är att ha anfangen en bit upp på land eller ledverk.

Sandöbron, rekordlångt bågspann i trä rasade 31 augusti 1939. 18 byggnadsarbetare omkom.

Till bygget av formen hade använts 2x8 tum plankor på högkant som spikades ihop med 60 ton 10 tums spik, formen för bågen vägde 1000 ton.



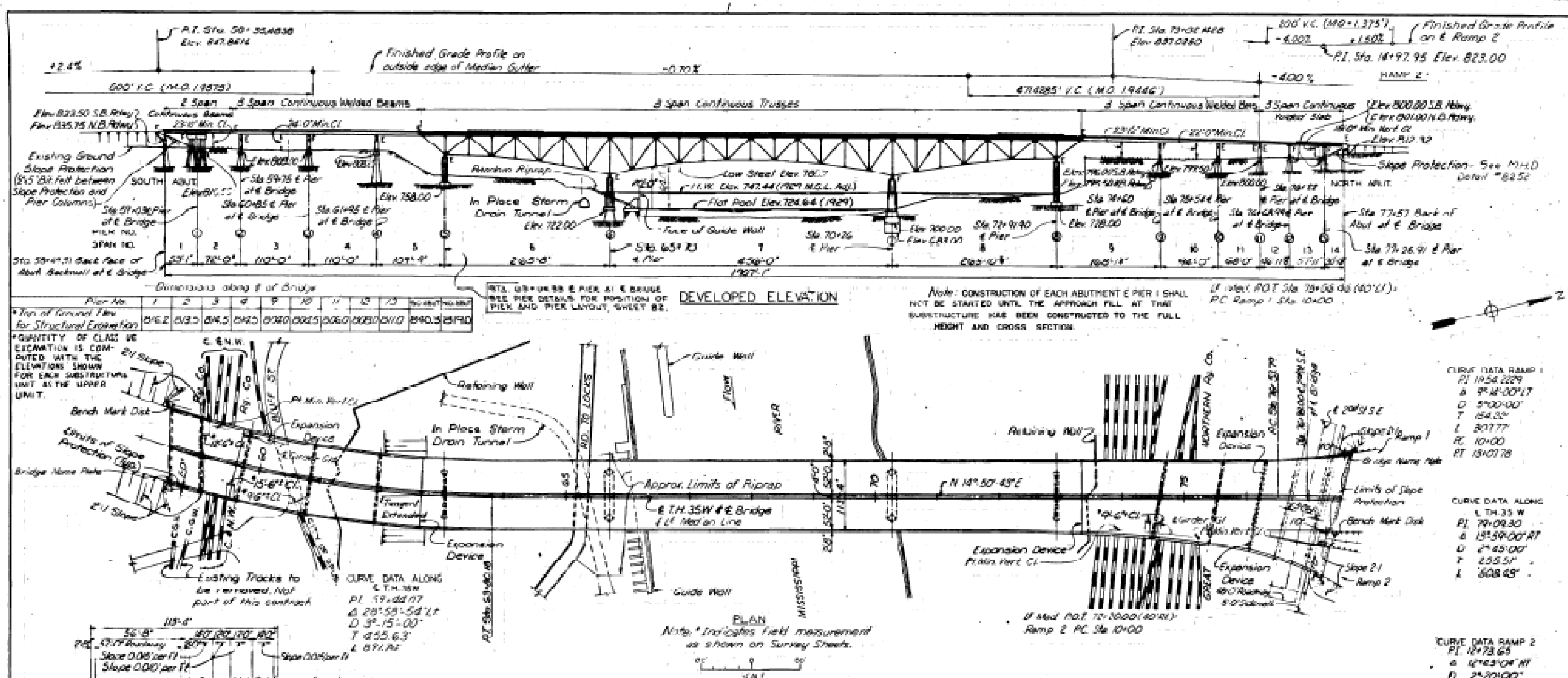
Efter detta byggdes bron upp igen, med den skillnaden att denna gång pålades i älvbottnen för att bära upp gjutformen för bågen, och Sverige fick ett rekordlång bågspann i betong, 269 meter.

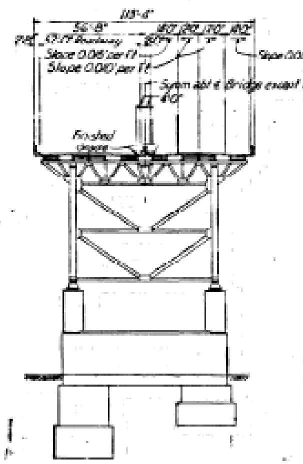


- **<u>Minnesota I-35 Bridge över Mississippi River</u>**

- Byggår: 1967
- 8 filer motorvägstrafik
- Bredd 34,5 meter
- Längd 581 meter
- Största spann 139 meter, h = 11-18 meter
- Fjorton spann: 3 fackverkstyp, 9 av stålbalkstyp, 2 betongspann
- Trafik: 140.000 fordon/dag(nr 5 i Minnesota)
- 1:a augusti 2007 rasade huvudspannen ihop under trafiken,
  4 av 8 filer dock avstängda p g a reparationer av däcket
- 13 personer dog och 100 skadades
- Klassades 2005 som ”structurally deficient”

- http://www.clevelandleader.com/node/2559





INDEX OF DRAWINGS

CONTRACT B

CONTRACT B CONSISTS OF CONSTRUCTING SOUTH AND NORTH ABUTMENTS, PIERS 1,2,3,4,9,10,11,12 AND 13, AND SUPERSTRUCTURE.

BENCH MARKS

B.M. #4 Elev. 830.82 (1929 Adj.)
Top Hyd't 150' Rt ℄ Sta 59+00
B.M. #5 Elev. 778.41 (1929 Adj.)
Top of Concrete Post 200' Rt ℄ Sta 62+00
B.M. #7 Elev. 749.64 (1929 Adj.)
Spk. in P.P. 163' Lt ℄ Sta 70+50
B.M. #8 Elev. 807.97 (1929 Adj.)
Spk. in Chwd. 15' Lt ℄ Sta 76+10
All bridge elevations are based on 1929 Adj.

NOTES

Abutments and Piers shall be at positions shown in Elevation for steel spans measured at normal temperature of 45° F.
Navigation lights not shown

MICRO-FILMED

I hereby certify that this plan was prepared under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

A. E. Mannes
Date 3-4-1965 Reg. No. 5289

DESIGNED BY
SVERDRUP & PARCEL AND ASSOCIATES, INC.
ENGINEERS - ARCHITECTS
ST. LOUIS, MO.

T. H. 35W
STATE OF MINNESOTA
DEPARTMENT OF HIGHWAYS

BRIDGE NO. 9340

T.H. 35W OVER RAILROADS, BLUFF ST., MISSISSIPPI RIVER AND 2ND ST. S.E. IN MINNEAPOLIS
53-72-110-110-77 WELDED BEAM SPANS
266-456-266 DECK TRUSS SPANS
130-94-68 WELDED BEAM SPANS
47-58-30 VOIDED SLAB SPANS
2-52' ROADWAYS, 2-1'-6" SAFETY CURBS, 4' RAISED MEDIAN

GENERAL PLAN AND ELEVATION

SEC. 24 & 25 T29N R24W
HENNEPIN COUNTY
APPROVED - 5-18-65

BRIDGE ENGINEER
DEPUTY CHIEF ENGINEER ENGINEERING


21

"I am totally puzzled as to why both ends of the bridge would come down all at once. When my colleague tested it, it was very low stress," said Ted Galambos, a University of Minnesota engineering professor.

"I don't think it was overload, so it could have been either some fatigue, failure or some sudden buckling that would cause the failure."

"Computers and modeling techniques are just light years from what was available 40 years ago," said Ted Galambos, a professor emeritus of structural engineering at the University of Minnesota and an expert in the stability of structural steel. "Now we can have an idea and we can test that on a computer in a few hours."

Hello again, Peter. I hope this e-mail finds you well, and that you enjoyed your Christmas and New Year's celebrations.

Concerning the I-35 Bridge Collapse in Minnesota, I contacted the National Transportation Safety Board (NTSB) to find out the latest information on the investigation. The NTSB has put out four (4) press releases updating the investigation (http://www.ntsb.gov/pressrel/pressrel.htm). The press releases do not make any conclusions about the root cause of the collapse. Unfortunately, they are not permitted to talk further about the investigation until it is completed. There is no estimate of when they plan to finish the investigation.

Harry White 2nd, PE
NYSDOT
Office of Technical Services
Transportation Research and Development

NTSB Advisory
National Transportation Safety Board
Washington, DC 20594
October 23, 2007

FOURTH UPDATE: NTSB INVESTIGATION OF MINNESOTA BRIDGE ACCIDENT

Washington, DC -- The following is an update on the National Transportation Safety Board's investigation of the I-35W bridge collapse in Minneapolis, Minnesota on August 1, 2007.

The NTSB investigation of the I-35W bridge collapse continues. Approximately 30 investigators are working on-scene and at headquarters to determine the probable cause of this accident. Minnesota Department of Transportation (MNDOT), the Federal Highway Administration and other parties continue to assist in this investigation.

"Since the start of this accident investigation, we have made substantial progress, in recovery, documentation, and data gathering," said NTSB Chairman Mark V. Rosenker. "However, several of our investigators are still on-scene and we are in the midst of a complete and thorough analysis of this information."

On Friday, October 12, NTSB investigators completed their work at the location of the bridge collapse and released the site to MNDOT.

NTSB investigators are conducting a detailed examination of the failed bridge structure. Bridge components relevant to the investigation are being kept at Bohemian Flats, a restricted, secure location south of the collapse scene. Principal components of particular interest will be shipped to the NTSB when the on-scene work is concluded.

"As part of its investigation, Safety Board investigators are meeting with persons who were on the bridge at the time of the collapse," said Rosenker. These individuals are reviewing a diagram of the I-35W Bridge that include vehicles and equipment in estimated pre-collapse locations to refine estimates of the loading of the bridge.

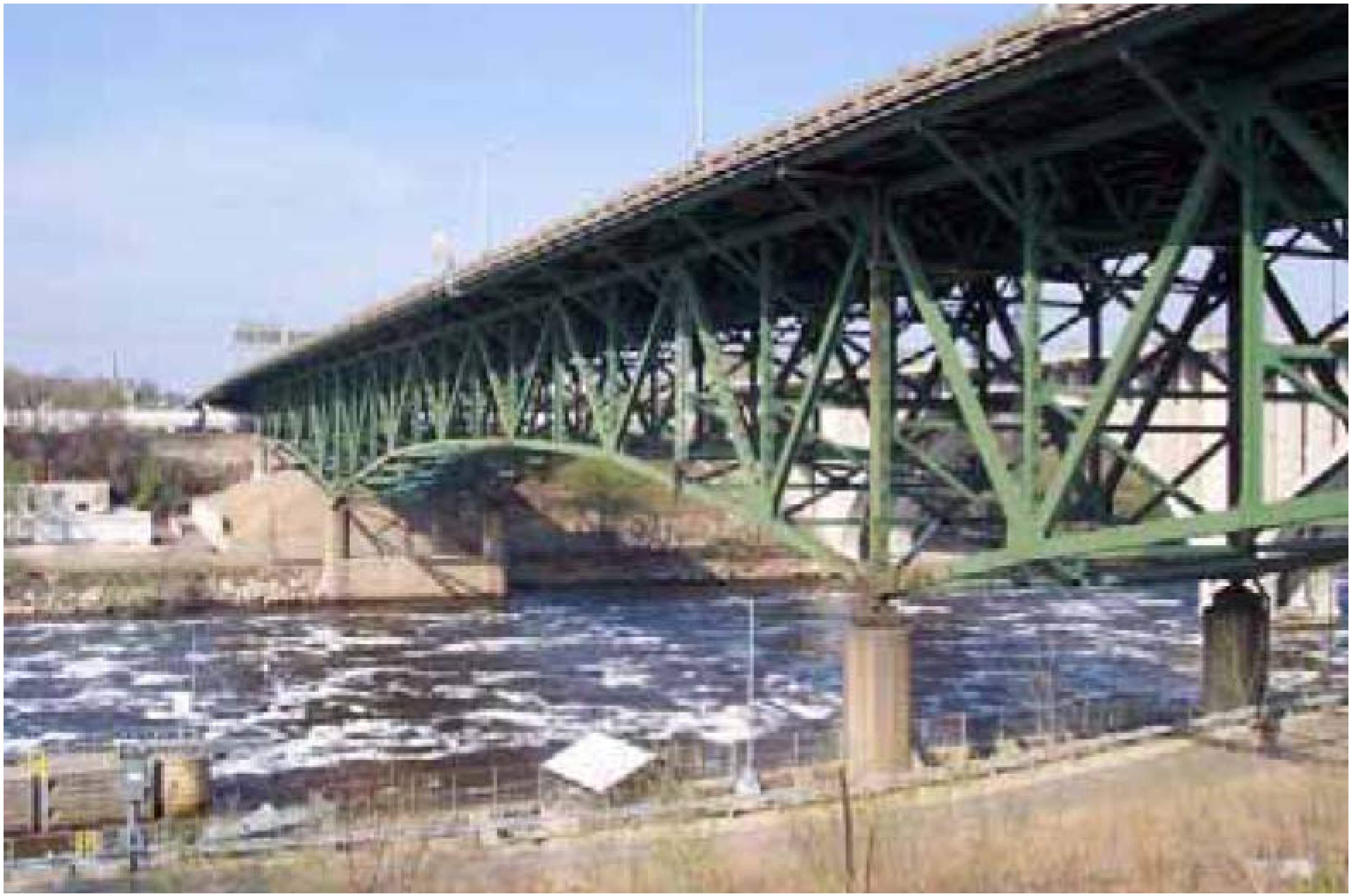
"The NTSB's on-scene phase of the investigation is expected to conclude in late November," said Rosenker. "However, as the investigation continues, investigators will visit Bohemian Flats for further evaluation of components from the bridge, if that should be necessary. "

NTSB Media Contact: Terry N. Williams (202) 314-6100
williat@ntsb.gov

FRACTURE CRITICAL BRIDGE INSPECTION

JUNE 2006 In-Depth Report

Prepared For
Minnesota Department of Transportation
Office of Bridges & Structures



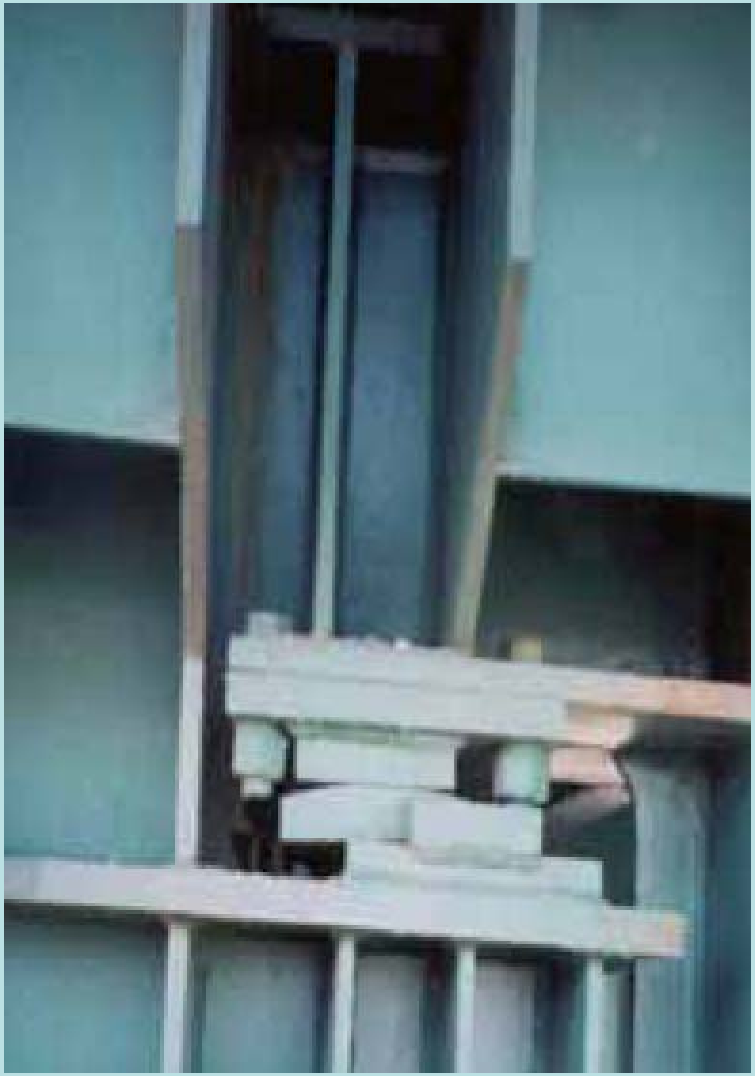
Long Term Repair Recommendations

- The long term plans for this river crossing need to be defined with replacement, re-decking, etc. Due to the "Fracture Critical" configuration of the main river spans and the problematic "crossbeam" details, and fatigue cracking in the approach spans, eventual replacement of the entire structure would be preferable.

Immediate Maintenance Recommendations

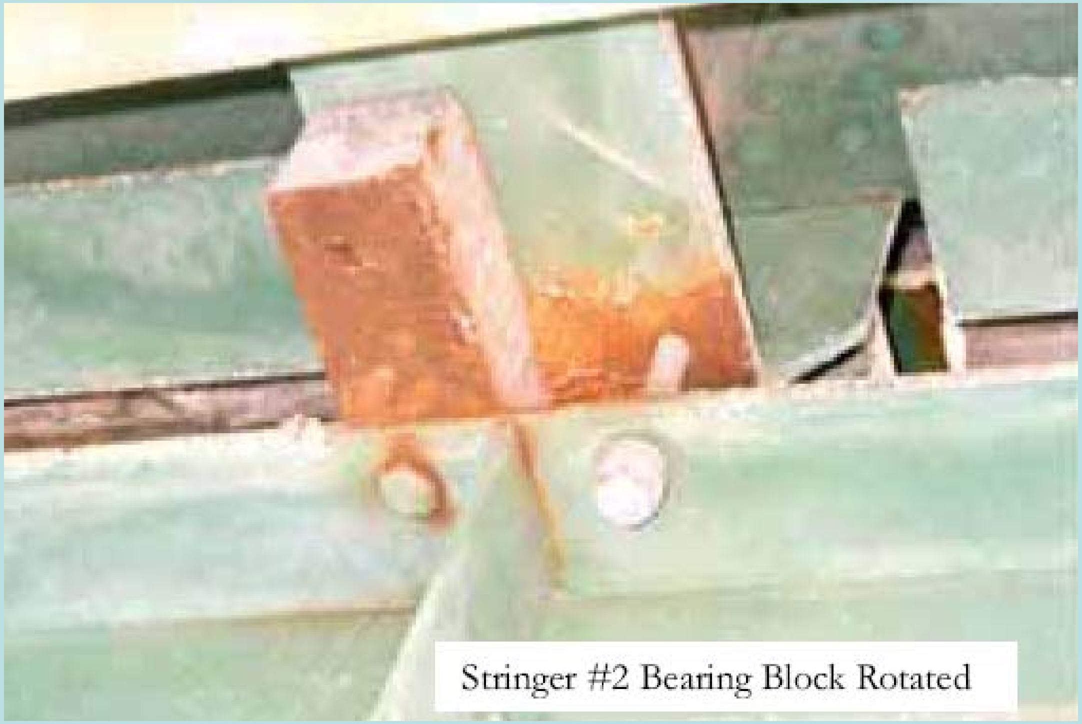
- Fatigue cracks at girder #1C (NBL), crack at the diaphragm bottom cutout, NE side measures 2" ("front face") and NW side measures 2-½" ("back face"). Fatigue cracks a girder #3 (NBL), crack at the diaphragm bottom cutout, measures 1-½" (both sides). The cracks are located in negative moment regions where the diaphragm web stiffener was not welded to the top flange and were pervious fatigue cracks occurred and were repaired in 1998 and 1999. These areas should be inspected next year for any lengthening of the cracks and drilling of possible stress relief holes.

- The hinge joint in span #2 is locked in full expansion several beam-ends are contacting, and the hinge bearings are "frozen" and no longer functioning. Consequently, pier #1 has tipped slightly to the north, and the south abutment bearings are in full contraction. This area should be thoroughly inspected.



on hinge area. Additionally, the tops of the beam ends are contacting at the top flange or at the web along this joint. [94/2005] All hinge assemblies are expanded beyond tolerance; sliding plates extend 4" or more beyond the base plates, reducing bearing capacity. At beam #10, the sliding plate has tipped, falling off the base plate, and is preventing the joint from opening. [2005] Hinges should be flushed.

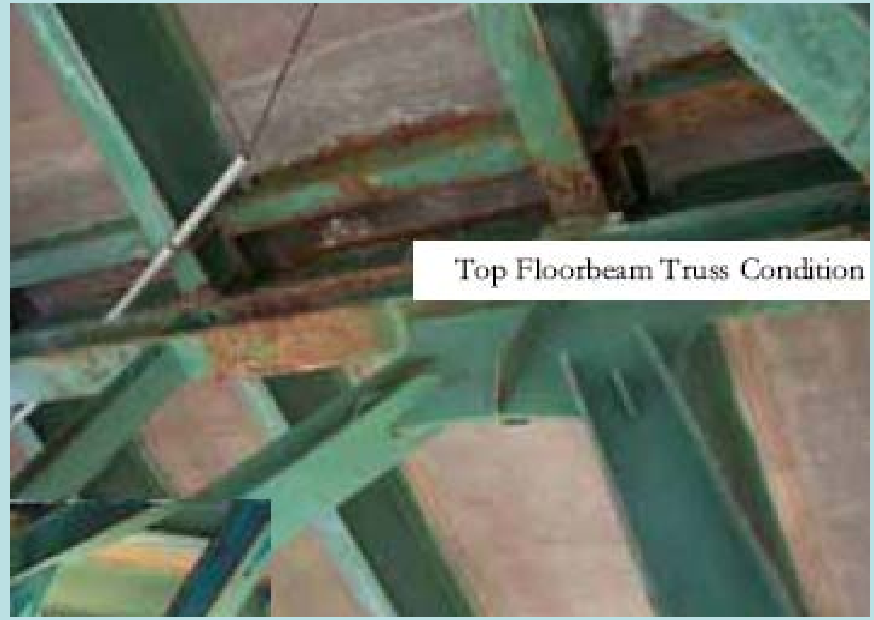
Sliding Plate @ Beam 5 NBL



Stringer #2 Bearing Block Rotated

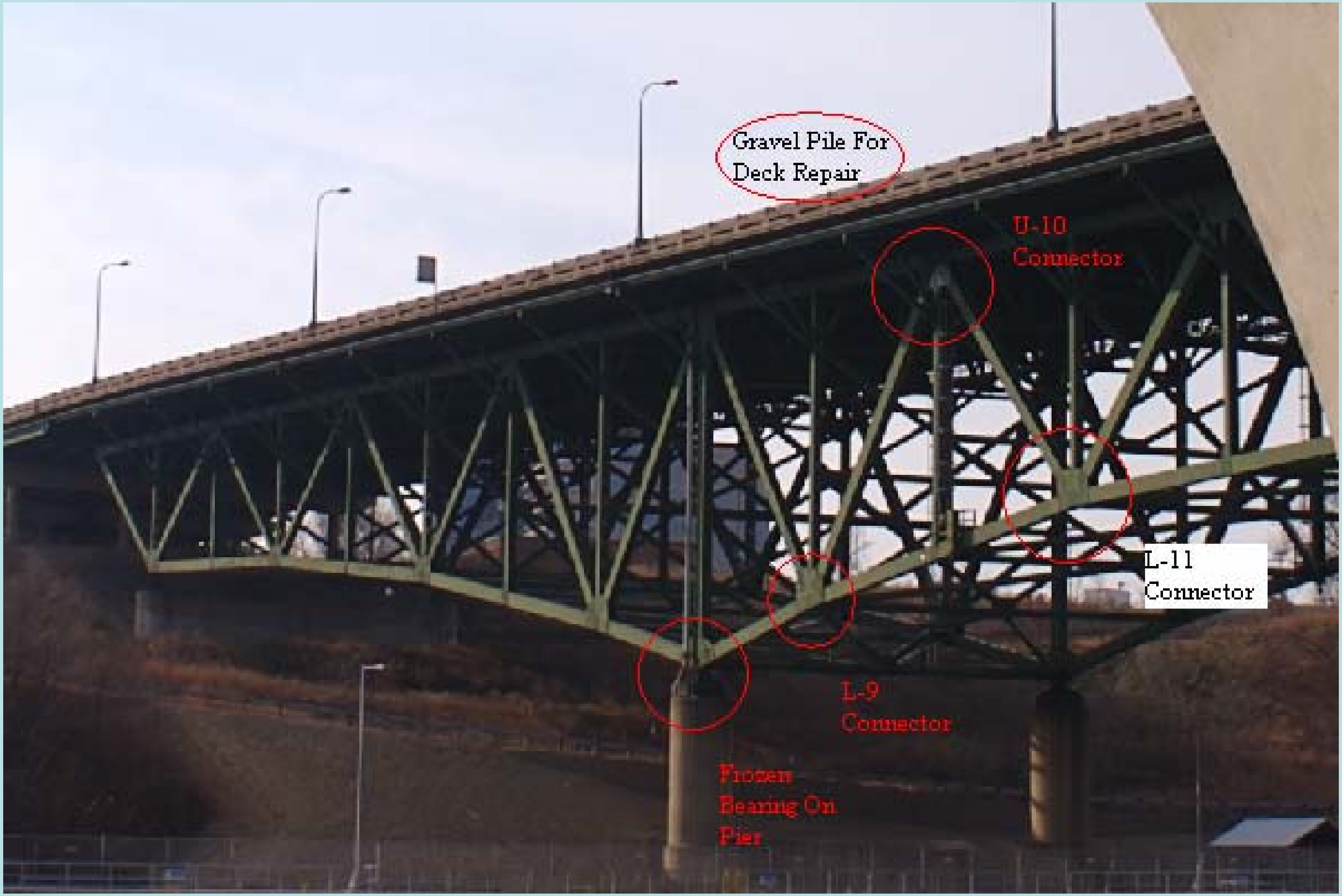
Stringer #2 (south side): bearing block has rotated 90°.

Top Floorbeam Truss Condition



Top Floorbeam Truss Condition

I-35W Bridge Collapse
Bridge Collapse Investigation Focus Area — October, 2007
By John A. Weeks III



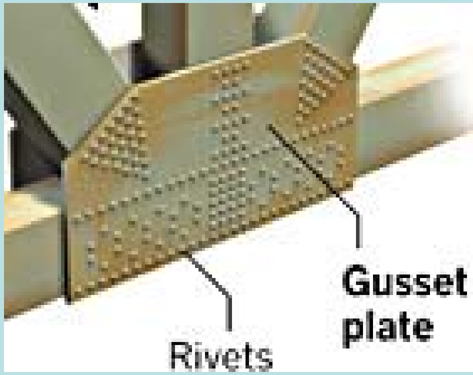

Southbound
Traffic
South East
Support Pier
Northbound
Traffic

The situation before the crash is that the south end bearings were frozen. Post collapse views show that the bearing have not been moving. These bearing are in place to allow the entire bridge to move as it expands and contracts during heating and cooling cycles. With the bearing inoperative, the bridge would have to flex and bend. To aggravate the situation, the Twin Cities area had been experiencing a spell of unusually hot weather, with the temperature being 91 degrees at the time of the collapse.

A second unusual factor is that the bridge was undergoing repair work on the deck. The normal 8 lanes were reduced to 2 lanes each direction, with two lanes each direction being closed for repair work. The northbound lanes had a large pile of gravel placed right above the U-9 and U-10 connector joints.

The third leg of the disaster concerns the gusset plates that held the beams together at the connector joints. These plates vary from one-half inch to one inch in thickness. There is speculation that the one-half inch plates may have been too thin to support the weight of the bridge, a design flaw that may have been an accident waiting to happen. In addition, recent inspections have found that rust was attacking these gusset plates. The L-11 gusset plate had lost one-half of its thickness in places due to rust. To aggravate this situation, anti-ice solution and salt may have collected in this area speeding up the corrosion, and bird droppings may have accumulated in this area making inspections all the more difficult.

The Minneapolis Star Tribune reports that connectors L-9, U-10, and L-11 all show evidence of pre-collapse damage. The failure of any one of these gusset plates would start a chain reaction of failures that would lead to the collapse of the bridge.



Charles J. Murray, Senior Technical Editor -- Design News, November 19, 2007

Discussions of fatigue have gained momentum in the wake of the bridge collapse in Minneapolis in August and following news that the Federal Highway Administration has designated countless bridges across the country as "structurally deficient." Experts and forensic engineers appearing on CNN and elsewhere in the national media have demonstrated the phenomenon by bending paper clips until they pass their elastic limits. The underlying message: Fatigue is causing plastic deformation in the supporting members of the bridges prior to failure

Engineers worry about overloaded trucks and construction equipment passing across bridges. Over the course of 40 years, with trucks getting larger and the number of overloaded trucks growing, damage becomes irreversible, they say.

At the same time, fatigue can be aggravated by corrosion. Corrosion fatigue, which reduces the designated fatigue strength of steels, can be caused by chemicals, such as salt, or by something as seemingly innocuous as bird droppings.

Är USA:s infrastruktur körd i botten?

It would be so expensive to fix hundreds of thousands of bridges that it's just not going to happen. But these numbers highlight the problem of the nation's infrastructure. No word is likely to make taxpayers' eyes glaze over more quickly. As a result, officials at all levels of government tend to defer maintenance on bridges and roadways; the voters wouldn't stand for the required expenditures, estimated at more than $9 billion a year. They might, however, be willing to pay for more frequent and thorough inspections, which could distinguish the structurally deficient bridges in imminent danger of failure from those that aren't.

In Minnesota, Gov. Pawlenty announced an immediate emergency round of inspections of all of the state's bridges, starting with the three that have the same structure as the crumbled Minneapolis span.

"The country is behind on infrastructure, and improvements need to be made," Pawlenty told reporters. "Anyone who looks at the national picture or the national statistics and says we don't have problems would be naive."

Time Magazine reported by Maxwell Bryer, Thursday, Aug. 02, 2007

Några möjliga rasorsaker-sammanfattning

Brons lager hade fastnat och rörliga fogar var i ytterläge med kontakt mellan balkdelar, samt mellanläggsplåtar på väg att kalva ut. Ger extra krafter i längsled, som förutom normalkraft i stänger skulle kunna göra att bron ramlar av något stöd.

Bron var på många ställen rejält rostig, vilket gör att spänningarna på orostat material stiger, samtidigt som bron där tål mycket lägre spänningsväxlingar. Utmattningslasterna torde ha ökats avsevärt sedan bron konstruerades på 1960-talet.

Knutplåtarna i knutpunkterna kan ha utlöst raset.

Ofta samverkar flera orsaker vid ras, och den slutliga rapporten lär vara färdig under 2008. Dock kan följande videoklipp peka på vad som kan ha hänt. Man säger bland annat att skarvplåtarna hade halva erforderliga tjockleken.(ca 12 mm i st f 25 mm). Man har funnit 16 trasiga skarvplåtar på olycksplatsen.

http://www.chicagotribune.com/news/nationworld/la-na-bridge16jan16,0,3774857.story

Washington, DC - The National Transportation Safety Board today issued a safety recommendation:

The recommendation is made to the Federal Highway Administration (FHWA) and states: "for all non-load-path- redundant steel truss bridges within the National Bridge Inventory, require that bridge owners conduct load capacity calculations to verify that the stress levels on all structural elements, including gusset plates, remain within applicable design requirements, whenever planned modifications or operational changes may significantly increase stresses." "Although the Board's investigation is still on-going and no determination of probable cause has been reached, interim findings in the investigation have revealed a safety issue that warrants attention," said NTSB Chairman Mark V. Rosenker. "During the wreckage recovery, investigators discovered that gusset plates at eight different joint locations in the main center span were fractured. The Board, with assistance from the FHWA, conducted a thorough review of the design of the bridge, with an emphasis on the design of the gusset plates. This review discovered that the original design process of the I-35W bridge led to a serious error in sizing some of the gusset plates in the main truss."

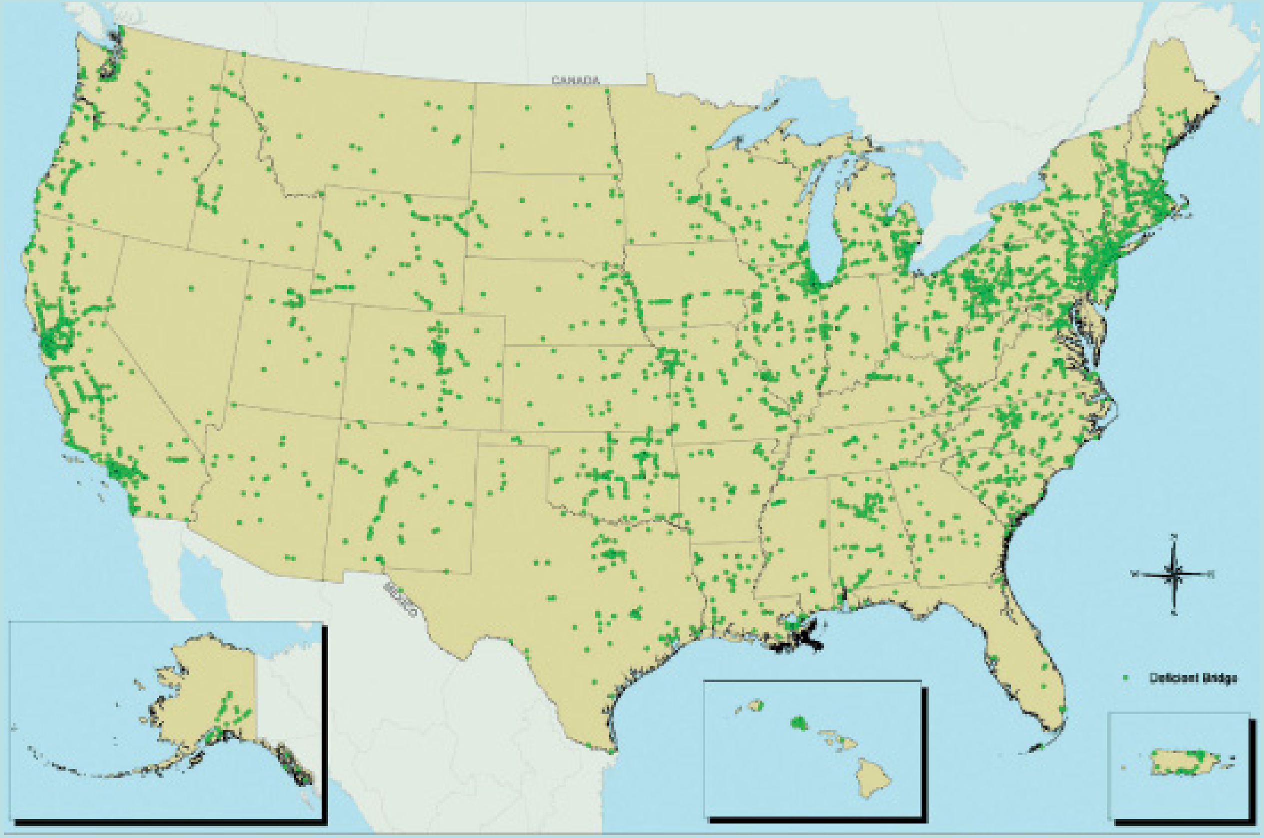
Undersized gusset plates were found at 8 of the 112 nodes (joints) on the main trusses of the bridge. These 16 gusset plates (2 at each node) were roughly half the thickness required and too thin to provide the margin of safety expected in a properly designed bridge.

Rekommendation 15:e january

In fact, this is the only bridge failure of this type of which the Safety Board is aware. However, because of this accident, the Safety Board cannot dismiss the possibility that other steel truss bridges with non redundant load paths may have similar undetected design errors. Consequently, the Safety Board believes that bridge owners should ensure that the original design calculations for this type of bridge have been made correctly before any future major modifications or operational changes are contemplated.

Therefore, the National Transportation Safety Board makes the following recommendation to the Federal Highway Administration:

For all non-load-path-redundant steel truss bridges within the National Bridge Inventory, require that bridge owners conduct load capacity calculations to verify that the stress levels in all structural elements, including gusset plates, remain within applicable requirements whenever planned modifications or operational changes may significantly increase stresses.



Approximately 12.4 percent of all bridges rated by the Federal Highway Administration have been declared structurally deficient. What exactly does this mean? “It doesn’t mean you have cancer or anything like that, it could mean you have acne,” says Sam Schwarts, former chief engineer for NYC bridges. “It means that you have a condition that has to be paid attention to, it doesn’t mean that the bridge has to be shut, but it could in the very worst case mean that you have terminal cancer; structurally deficient is a very broad term, and there are some bridges that need to be in the ICU.”

Fler broar skall snabbkollas(15/1 2008)

ST. PAUL, Minn. -- Minnesota appreciates the progress the NTSB has made in the investigation and its willingness to share preliminary findings.
The findings announced today by the NTSB about the gusset plates are valuable not only to Minnesota but the nation.
Because the NTSB first noted concerns about weight loads and gusset plates in August, Mn/DOT took a proactive step in beginning a review of the design of gusset plates on similar truss bridges in Minnesota.
Mn/DOT already has started reviewing these gussets on existing truss bridges similar to I-35W and will expand that review to include all truss bridges. There are 23 truss bridges on the state highway system and 36 on the local road system. See Minnesota Highway Truss Bridge Lists (39kb PDF, 2 pages)
Mn/DOT has completed the gusset check on the Highway 23 bridge over the Mississippi River in St. Cloud and no deficiency has been found.
Mn/DOT staff also has completed checking the most heavily loaded gussets on Highway 243 bridge over the St Croix River near Osceola; and the Highway 123 bridge over the Kettle River near Sandstone. No deficiencies have been found and they are in the process of developing computer models of both bridges to complete all gusset checks. That is expected in the next month.
Mn/DOT has also retained two engineering firms to perform load ratings on several truss bridges, these are among Mn/DOT's larger trusses of complex design. Those firms are LHB Engineers of Duluth and WSB and Associates of Minneapolis. Mn/DOT has expanded that work to include a review of gusset plates. The bridges involved in those contracts are:

- Highway 43 over the Mississippi at Winona
- Highway 23 over the Mississippi in St. Cloud (gusset plate review completed)
- Highway 61 over the Mississippi at Hastings
- Highway 63 over the Mississippi at Red Wing
- Highway 2 over the Red River at Grand Forks
- Highway 535 in Duluth - Blatnik Bridge
- Highway 99 over the Minnesota River at St. Peter

Sean Snyder, Associate Editor -- Design News, September 21, 2007

On Sept. 19, the Minnesota Department of Transportation (Mn/DOT) announced the award of Minneapolis' I-35W bridge rebuild contract to the joint venture between Flatiron Constructors, Inc. and Manson Construction, according to a press release on the Mn/DOT website. Flatiron-Manson had the highest technical score out of the four bidding contractors, with a 91.47 compared to a 67.8 from Walsh- American, a 65.91 from McCrossan and a 55.98 from Ames/Lunda.

Flatiron’s bid was the highest of the four bids at nearly $234 million and is proposed to take the longest at 437 days for a complete rebuild according to the release.

MN-DOT is promised the people of Minnesota that the new bridge will be open on December 24, 2008.